R E P O R T R E S U M E S

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AUTOMOTIVE DIESEL MAINTENANCE 1. UNIT XIX, I--ENGINE TUNE-UP--CUMMINS DIESEL ENGINE, II--FRONT END SUSPENSION AND AXLES.

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THIS MODULE OF A 30-MODULE COURSE IS DESIGNED TO DEVELOP AN UNDERSTANDING OF DIESEL ENGINE TUNE-UP PROCEDURES AND THE DESIGN OF FRONT END SUSPENSION AND AXLES USED ON DIESEL ENGINE EQUIPMENT. TOPICS ARE (1) PRE-TUNE-UP CHECKS, (2) TIMING THE ENGINE, (3) INJECTOR PLUNGER AND VALVE ADJUSTMENTS, (4) FUEL PUMP ADJUSTMENTS ON THE ENGINE (PTR AND PTG), (5) HISTORY OF FRONT AXLES, AND (6) AXLE LOADS. THE MODULE CONSISTS OF A SELF-INSTRUCTIONAL BRANCH PROGRAMED TRAINING FILM "PRINCIPLES OF TUNE-UP--CUMMINS DIESEL ENGINE" AND OTHER MATERIALS. SEE VT 005 655 FOR FURTHER INFORMATION. MODULES IN THIS SERIES ARE AVAILABLE AS VT 005 655 - VT 005 684. MODULES FOR "AUTOMOTIVE DIESEL MAINTENANCE 2" ARE AVAILABLE AS VT 005 685 - VT 005 709. THE 2-YEAR PROGRAM OUTLINE FOR "AUTOMOTIVE DIESEL MAINTENANCE 1 AND 2" IS AVAILABLE AS VT 006 006. THE TEXT MATERIAL, TRANSPARENCIES, PROGRAMED TRAINING FILM, AND THE ELECTRONIC TUTOR MAY BE RENTED (FOR $1.75 PER WEEK) OR PURCHASED FROM THE HUMAN ENGINEERING INSTITUTE, HEADQUARTERS AND DEVELOPMENT CENTER, 2341 CARNEGIE AVENUE, CLEVELAND, OHIO 44115. (HC)

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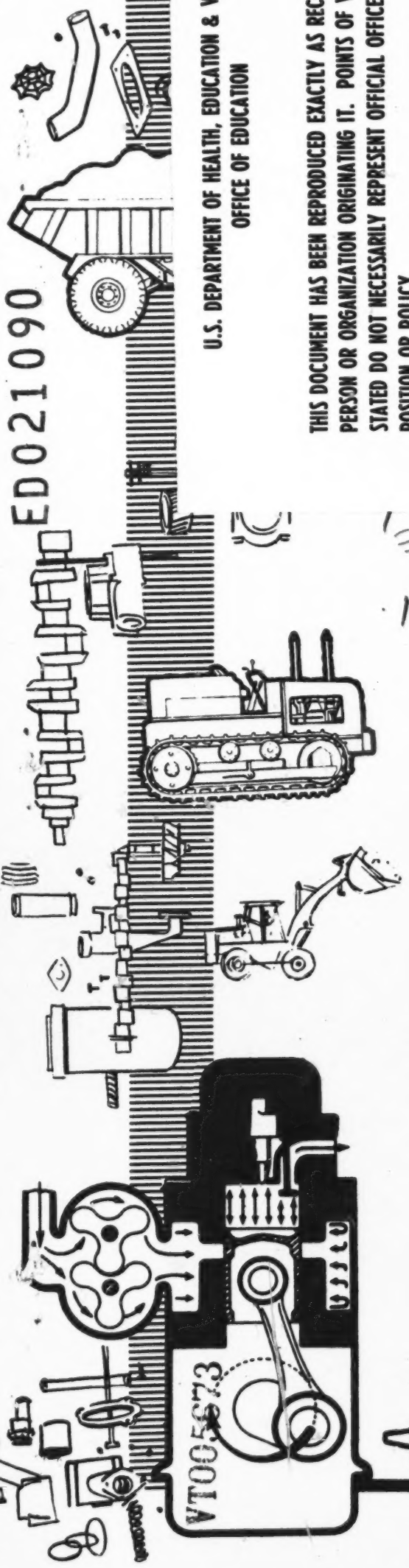

STUDY AND READING MATERIALS

AUTOMOTIVE DIESEL MAINTENANCE 1

I -- ENGINE TUNE-UP -- CUMMINS DIESEL ENGINE

II -- FRONT END SUSPENSION AND AXLES

UNIT XIX

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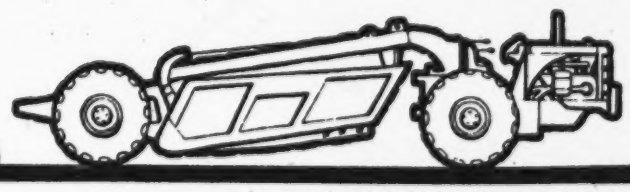

This unit is divided into two parts. The first part is a detailed explanation of how to tune a Cummins engine without using test stand equipment. You will recall that in Unit AM 1-13, the fuel pump and injectors were removed from the engine and placed on a test stand. The second part of this unit is a brief discussion of front end suspension and suspension components of a vehicle.

I -- ENGINE TUNE-UP -- CUMMINS DIESEL ENGINE

SECTION A -- PRE TUNE-UP CHECKS

One of the most important things that a diesel mechanic must remember is when a tune-up of an engine is necessary. Most companies maintaining heavy mobile equipment keep records of each vehicle which enable them to watch performance very carefully. These records indicate such things as: hours of operation since last oil change, last tune-up, whether it is a new engine, parts that have failed, warranty, etc. Hence, the records give the mechanic some guidelines to follow. All diesel engines, regardless of type should be tuned-up when:

1. A new engine is installed.
2. A new engine has run 100 hours or 300 miles.
3. Every 300 hours of operation.
4. Performance is unsatisfactory.
5. An engine has just been overhauled.
6. The cylinder head assembly has been serviced.

Once it has been determined that a tune-up is required, the following steps should be followed, in sequence:

1. Steam clean the area surrounding the fuel pump, rocker box covers, and cam rocker lever assemblies. This prevents dirt from entering critical areas of the engine during adjustment.
2. Bring engine up to operating temperature.

3. Check engine timing, (not necessary on minor tune-ups).
4. Injector plunger adjustments.
5. Valve clearance adjustments.
6. Maximum high-idle, no load, speed check and adjustment.
7. Rear throttle stop screw adjustment.
8. Adjustment of fuel manifold psi.
9. Setting forward throttle stop screw and idle speed.
10. Torque the cylinder head(s). NOTE: This procedure differs with various models of Cummins engines; check the shop manual for these differences. The pre-tune check is now completed; let's move on to the actual tune-up.

SECTION B -- TIMING THE ENGINE

INJECTION TIMING -- Correct injection timing is essential, to insure proper engine performance. There are three methods of changing injection timing, depending on the type of engine. Remember however, that injection timing is not always performed during a normal tune-up, but should be performed after an engine overhaul, or when operating performance is poor.

Injection timing in the Cummins engine is controlled by the movement of the injector push rod. NOTE: There are three push rods per cylinder and of these the largest one, located in the middle socket, is the injector push rod. Also these push rods are hollow, therefore, they are sometimes referred to as "push tubes". The movement of the push rod is a result of the camshaft lobe; if the camshaft starts to lift the push rod before it should, we say the timing is advanced or early. If the camshaft lifts the push rod after it should, we say the timing is retarded or late.

To check injector timing install a timing tool suitable for the particular engine. Remove the injector to be checked and install the tool so that one rod of the tool is in a push rod socket and the other is resting on the piston, see Figure 1.

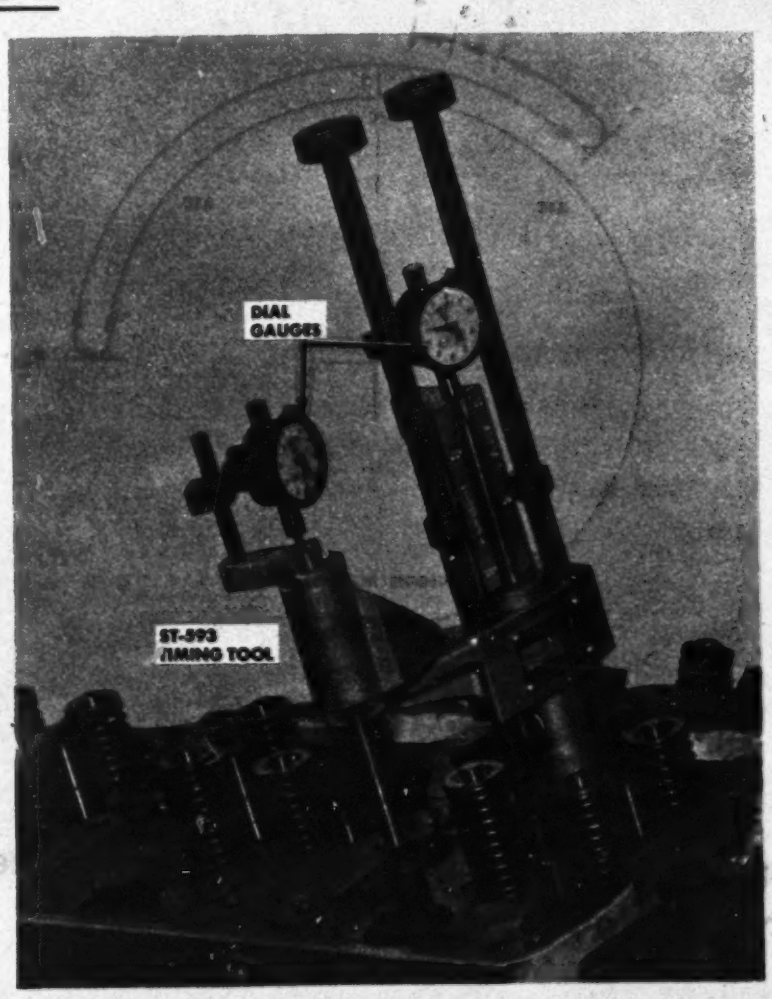

Fig. 1 ST-593 injector timing fixture.

NOTE: Three examples of timing tools are: ST-300 for NVH, NVHS, and VT-12 engines; ST-468 for 4 and 6 cylinder 4 7/8" and 5 1/8" bore engines; and ST-840 tool for V-6 and V-8 engines.

Also, the two dial indicators used on these tools in timing the engine must have a total travel of at least 0.250" and one with 1.0 inch of travel makes timing easier.

After the proper tool has been installed, the following is the proper checking procedure: NOTE: Refer to Figure 2 when reading the following steps.

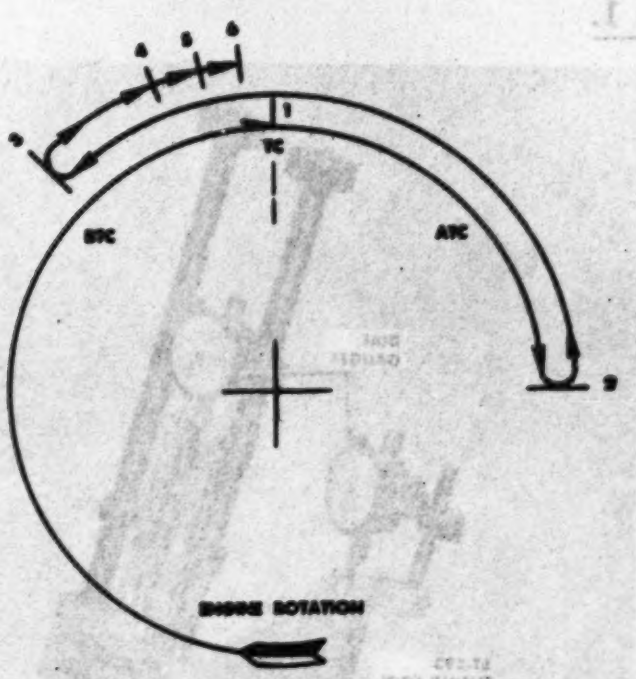

Fig. 2 Engine timing procedure.

STEP 1 Bar engine over until piston of cylinder being tested is at TDC (top dead center). Set indicator above piston at "0".

STEP 2 Advance engine to 90° ATC (after top center). The top of the tool rod above the piston will be at 90° mark, also the timing VS mark, on the water pump drive pulley will line up with the timing mark on gear cover case for the cylinder being tested. Set indicator above push rod to "0"; see Figure 3.

STEP 3 Bar engine opposite rotation to 95° BTC (before top center). This step takes up gear lash. The top of the tool rod above piston will be at 45° mark.

NOTE: This will be the second time the tool rod will reach the 45° mark. Remember, we were 90° ATC in Step 2, so we must go back past 45° ATC in reaching 45° BTC.

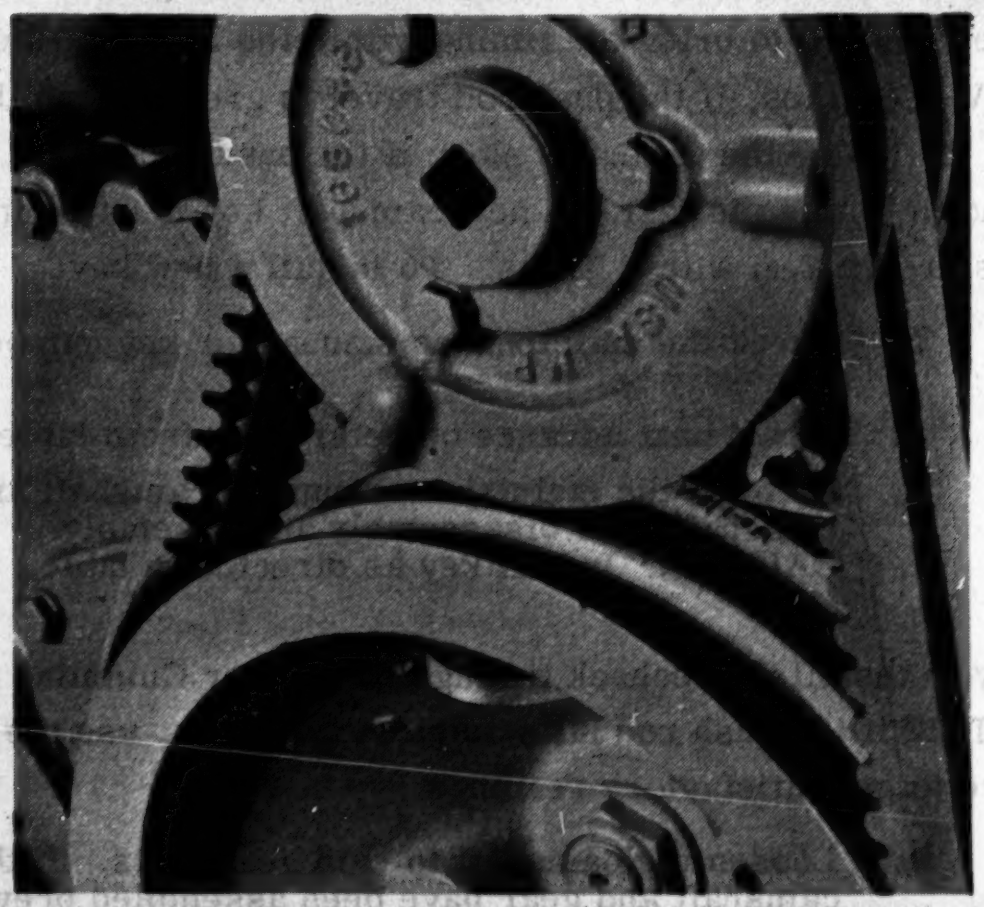

Fig. 3 Timing marks, water pump drive pulley.

STEP 4 Bar engine forward until piston is at a given reading below or lower than at top center position. This reading may be 0.2032" or 19° on some engines. The first stopping point is different with different engines. Next read the dial indicator above the injector push rod, and compare this reading with injection timing limits printed in engine shop manual.

NOTE: Remember, there are three methods of adjusting injection timing, on 4 and 6 cylinder inline engines if the downward travel of the push rod (from the 90° ATC position) is greater than the limits shown in the table, engine timing is slow. It can be corrected by adding gaskets, between the cam follower housing and cylinder block. The addition of one gasket

advances the timing approximately 1°. If the downward travel of the push rod is less than the limits shown in the table, timing is fast and gaskets should be removed to bring the timing within the limits of the tables. On V-6 and V-8 engines, if the push rod travel is greater than the limits shown in the table, the timing is slow; if the push rod travel is less than limits shown, timing is fast. A new camshaft key must be installed to bring push rod travel within limits. To install a new key:

a. Check the maintenance manual for key number currently being used.

b. Select next advance or retard key from table.

c. Refer to the maintenance manual camshaft and camshaft gear disassembly and assembly.
CAUTION: Install key as directed in table.

After key is installed, recheck timing. On larger Cummins engines, such as the VT-12 if the push rod falls outside the limits, use the following procedure to get satisfactory readings:

1. Loosen the camshaft to cam gear bolts. If the camshaft and gear have been assembled previously and dowelled, it will be necessary to remove the two dowel bolts. If the camshaft is new, the camshaft flange will not have the dowel-bolt holes.

2. Rotate the camshaft without moving the cam gear to advance or retard the timing and bring it within the specified limits.

CAUTION: Do not disengage the cam gear from the gear train. Oversize holes are provided to make this adjustment.

STEP 5 Continue to bar engine forward until piston is at a certain reading lower than top center position. On some engines this reading is 0. 0816" or 12° BTC. Again, check the manual for limits at this position.

STEP 6 Continue to bar engine forward until piston is at a certain reading lower than top center position. Again, this reading on some engines is 0. 0143 or 5° BTC and we will check to see if reading of push rod travel is within limits.

If we adjust injection timing by any one of the previous procedures and get a correct reading at Step 4, but are beyond limits at Step 5 and/or Step 6, then this indicates a worn camshaft and the camshaft must be replaced. The next step is to adjust the injector plunger and valves.

SECTION C -- INJECTOR PLUNGER AND VALVE ADJUSTMENTS

Injector plungers and valves should be adjusted before starting the engine the first time, after the first 50 hours service and at every "D" maintenance check thereafter.

The procedure in positioning engine for injector and valve adjustment is:

1. Pull the compression release lever back and block in the open position. This lifts all closed intake valves and makes it possible to turn the camshaft without working against compression.
2. Bar the engine in its operating direction to No. 1 top center firing position (on V's this would be the No. 1 of left bank). In this position -- and after the block is removed from the compression release lever -- both intake and exhaust valves will be closed in the No. 1 cylinder.
3. Continue to rotate the crankshaft in its operating direction one-quarter turn and the 1-6 VS mark will align with timing mark, see Figure 3.

   NOTE: On V engines like the VT-12 the timing "VS" marks will have an L or R after the "VS" mark -- meaning left or right bank.
4. The injector plunger and valves of No. 1 may now be adjusted.
5. Rotate the crankshaft in operating direction to the next "VS" mark corresponding to firing order of the engine.
6. Continue the above steps until all injectors and valves have been correctly adjusted.

   CAUTION: Two complete revolutions of the crankshaft are needed to set all injector plungers and valves. Injector and valves can be adjusted for only one cylinder at any one setting ("VS" mark), and that is the cylinder on the power stroke.

ADJUSTING INJECTOR PLUNGERS -- Adjust injector plungers when the engine is at the proper "VS" marking with the following procedures:

NOTE: The injector plungers must be set before the valves, because the upward flex of rocker shaft when injector is torqued would change the valve setting.

1. **Check threads of injector adjusting screw and nut to see that they are clean, well oiled, and free-turning.**
2. **With the engine in valve-set position, ("VS" mark) for injector being adjusted, turn the injector adjusting screw down until plunger contacts the cup, and advance an additional 15 degrees to squeeze oil out of cup. (This would be about 1/4 of a side of hex nut).**
3. **Loosen the adjusting screw one turn.**
4. **Use a torque screw driver or a small accurately calibrated torque wrench to tighten the adjusting screw. The torque specification will vary on different engines but on the VT-12 Cummins engine they are:**
   a. **Five foot-pounds or 60 inch pounds, with oil temperature at 70 F, or**
   b. **Six foot-pounds or 72 inch pounds, with oil temperature at 140 F.**

NOTE:

1. **If a torque wrench is used, it must have a screw driver adapter and it should read in one foot-pound or inch-pound divisions. If a foot-poumd scale is used, it should have a maximum capacity of no more than 15 foot-pounds, in order to be accurate.**
2. **A bar, screw driver, or any other type of hold-down tool is not to be used when adjusting rocker levers by the torque method. To do so would result in a false setting.**
3. **Template marks and adjusting clips are to be disregarded when using the torque method of injector adjustment.**

VALVE CROSSHEAD ADJUSTMENT --

1. Loosen the valve crosshead adjusting lock nut and back off the adjusting screw one turn.
2. Use light finger pressure at center of crosshead "A" to hold the crosshead in contact with the valve stem opposite adjusting screw "B", see Figure 4. Turn down the crosshead adjusting screw until it touches the valve stem under adjusting screw "C".
3. For new crossheads and guides, advance the crosshead adjusting screw 1 /3 of one hex (or 20°) more to straighten the stem in its guide and to compensate for slack in threads. On old style or worn crossheads and guides, it may be necessary to advance the screw as much as 30 degrees in order to straighten the stem in its guide.
4. Hold the adjusting screw in this position and tighten lock nut to 25/30 foot pounds.
5. Check clearance between crosshead and valve spring retainer with a wire gauge. There must be a minimum of . 025 inch clearance at this point.
6. Lock the adjusting screw in this position. Adjust both intake and exhaust valve crossheads in this manner.

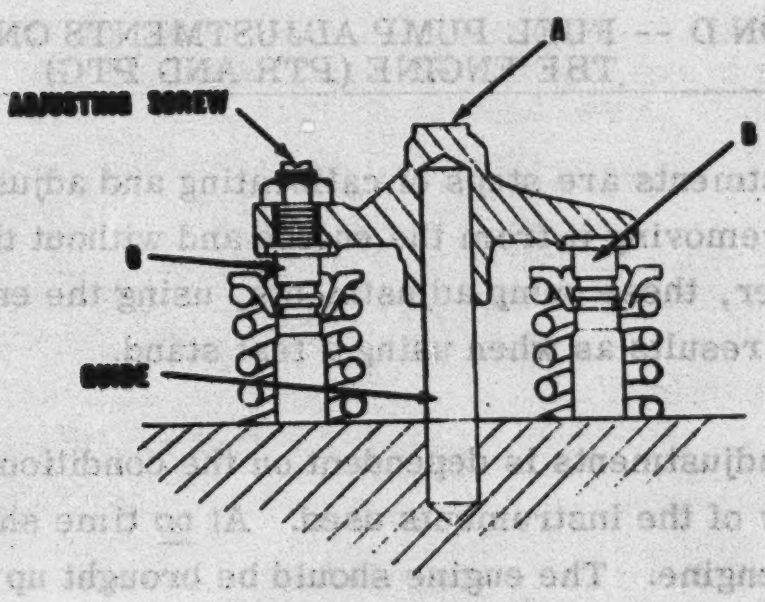

Fig. 4 Valve crosshead adjustment.

VALVE ADJUSTMENT --

1. The same engine position used in setting the injector is used for setting the intake and exhaust valves.
2. Make sure the compression release is in the run position before setting the intake valves.
3. Loosen the valve adjusting lock nut and back off the adjusting screw.
4. With a feeler gauge of proper thickness, for the valve being adjusted, inserted between crosshead and lever, turn the adjusting screw down until lever just touches the feeler gauge. After valves are at proper clearance, lock the jam nut.

   NOTE: Each engine model has a specific valve setting. The following is an example of valve settings used on the VT-12 engines:

   a. With oil temperature at 70 F:
      Intake valves 0. 016"
      Exhaust valves 0. 029"

   b. With oil temperature at 140 F:
      Intake valves 0. 014"
      Exhaust valves 0. 027"

5. Always make final injector and valve adjustments after the engine is warm; oil temperature 140 F.

SECTION D -- FUEL PUMP ADJUSTMENTS ON THE ENGINE (PTR AND PTG)

The following adjustments are steps of calibrating and adjustment for the fuel pump without removing it from the engine and without the use of test stand. However, these pump adjustments, using the engine, accomplish basically the same results as when using a test stand.

Accuracy of these adjustments is dependent on the condition of the engine, and on the accuracy of the instruments used. At no time should adjustment be made on a cold engine. The engine should be brought up to temperatures

between 140° to 160° F. Also, the valves and injectors should be set properly, according to specifications, as outlined in the preceding section.

If the fuel pump has been removed from engine for rebuild or general repairs and reinstalled, proper hook-up is necessary. The following is the procedure for pump hook-up:

1. Install fuel pump to accessory drive or to compressor with new gasket and proper rubber buffer or spline coupling and tighten securely.
2. Squirt clean lube oil into gear pump inlet hole. This aids gear pump fuel pick-up.
3. Connect the fuel pump copper line from the pump shut-off valve to the fuel manifold. The PTG type fuel pump should at this time be primed if the pump has been opened up. Fill the pump housing with clean fuel oil through the 1/8 inch pipe plug hole located on the top of the fuel pump body, formerly the pump drain line connection outlet on the PTR type pump. NOTE: This fuel priming step can be omitted when installing the PTR pump; instead install the fuel pump drain hose to the PTR pump. As was mentioned in earlier units, following are two ways to tell the pump apart:
   a. In the lower left hand corner of information plate the PTR pump is marked PR and the PTG pump is marked GR.
   b. The PTR pump pressure regulation cap, which is located on the back of the pump, is a 15/16" hex head type. The PTG cap, located where the PTR pressure regulator cap is located, has an allen or plug socket for tightening.
4. The throttle lever linkage should not be connected to the throttle lever, thus leaving the throttle free for pump adjustments.
5. Install an "accurate tachometer" to the fuel pump tachometer drive shaft connection. This drive shaft turns at one-half engine speed.
6. Connect the shut-off valve electrical connections properly, leaving the manual control button in a closed position.
7. Install pressure gauge ST-435 to shut-off valve at 1/8" pipe plug outlet hole on shut-down valve.
8. Connect ST-434 vacuum gauge to the gear pump suction connection and hook-up pump supply line. Tighten securely.

The engine may now be started and run (at 1500 rpm) until engine and fuel line are purged of air. If the fuel pump is newly rebuilt or has been opened up, it is necessary to start the engine with throttle one quarter open and hold firmly to retain engine speed at 600 to 800 rpm for three minutes. If the fuel system does not purge itself of air, check all fuel connections for tightness and for faulty pump and filter gaskets. The system must be free of air entrainment at all times before making any adjustments.

With the engine free of air, set or check governor speed. This is done by gradually advancing the throttle lever counterclockwise until maximum NO LOAD speed is obtained by holding throttle against rear throttle stop screw. High-idle no load speed is 6 to 8 percent greater than engine rated rpm on PTR type pump and 10 to 12 percent on PTG type pumps. For example: On a NH-220 Cummins engine that is rated at 2100 rpm the high-idle no load speeds would be between 2226-2268 rpm for a PTR type pump and 2310 to 2352 rpm for a PTG type pump. This check should be made with care. Don't advance throttle lever too quickly at the beginning of this governor speed setting.

The maximum high idle, no load governor speed can be adjusted correctly by removing the spring pack cover. Add or remove governor spring shims from beneath the governor high speed spring retainer. Add shims to raise rpm or remove shims to reduce speed. The following is the governor speed shim thickness to rpm ratio: On the PTR type pump 0.001" equals 4 rpm, on the PTG type pump 0.001" equals 2 rpm. Whenever the spring pack housing cover is removed for the above governor adjustments, it will be necessary to run engine until engine fuel system is purged of air before making other adjustments.

Next observe the ST-435 pressure gauge as the engine is accelerated to full throttle (this must be done quickly by using the throttle lever).

Maximum fuel psi is obtained by the increased engine speed. At this point the pressure gauge hand hesitates and quickly falls off due to the governor action at speed above engine rated rpm (high idle, no load). When this pressure drop occurs, observe this maximum pressure. (This procedure is referred to as "taking a snap reading"). Turn the rear throttle stop screw in or out until the greatest pressure can be obtained by snapping the throttle in open position quickly. After obtaining this maximum pressure, turn down rear throttle stop screw until pressure is reduced not more than 5 psi, and lock screw at this setting.

During this snap reading procedure, observe the ST-434 vacuum gauge. If vacuum exceeds 8" Hg reading on gauge a new main supply line fuel filter should be installed.

If the above procedure has been performed with care, the main fuel passageway in the throttle will be indexed or in the full fuel position when throttle lever touches rear throttle stop screw.

While making rear throttle screw setting note the maximum manifold pressure, and if manifold pressure is not according to engine manifold pressure specifications, adjust and correct manifold pressure psi as outlined below, not with the rear throttle stop screw.

On the PTR type pump, manifold pressure, (mp) must be set by the snap reading method: Accelerate throttle from idle to maximum full throttle quickly and record highest psi. Add or remove fuel adjustment shims, (sometimes called pressure shims), from under fuel adjustment plunger (nylon) to the correct engine fuel mp listed under fuel pump calibration data (see manual). Remove shims from fuel adjustment so that plunger will increase or raise fuel mp. NOTE: A good way to remember to remove or add shims to raise pressure is: On the PTR pump R means R & R, "remove and raise". On PTG pumps this is the opposite, remove shim to lower or decrease pressure.

The PTG fuel mp is calibrated by following the same snap reading procedure as for the PTR pump. Correct mp is obtained by adding or removing fuel adjustment shims from under the fuel adjustment plunger located in the rear of the throttle shaft. Remember the fuel adjustment plunger was located in the by-pass valve of pressure regulator.

The final adjustments of setting forward throttle stop screw and idle may be made in the following procedure:

1. Start engine and run with throttle lever in idle position. Hold the throttle lever firmly in the idle position and turn in forward throttle stop screw until engine speed begins to increase. This will occur when main fuel passageway in throttle begins to align enough to allow fuel to pass through the throttle, (this is called throttle leakage and the more throttle leakage we have, the faster the idle will be).
2. Now back the forward throttle stop screw out two full turns. This eliminates any throttle leakage and the throttle lever may have to be held by hand in a position to maintain engine speed.
3. Remove plug from governor spring pack cover and adjust idle speed until you reach 10 to 20 rpm below desired idle speed, replace plug. NOTE: This idle adjustment must be made while engine is not running on the PTG fuel pump. Otherwise pump will lose its prime. Many mechanics have a special screw driver with a 1/8" plug fitting on a shank of the screw driver which prevents pump from sucking air and losing prime; with this type screw driver PTG pumps do not have to be stopped to make above adjustment.
4. Make sure engine is completely purged of air.
5. Turn forward throttle stop screw in until idle speed increases 10 to 20 rpm or to desired idle speed and lock screw. NOTE: The following test can be made to check above adjustment: de-accelerate engine from full throttle speed to idle position and record the time required to go from full throttle to idle speed. If the time takes longer than 6 seconds, then forward throttle stop screw has been turned in too far, and we have too much throttle leakage. Throttle leakage is very important because it assures that there is always fuel in manifold and injectors, and thereby assures sufficient fuel for quick acceleration and adequate lubrication of injectors and other moving parts.

The sequences of the steps in Section D should be followed only when complete calibration of the PT fuel pump is necessary. However, individual adjustment can be made by following the steps that pertain to the adjustment needed.

This completes the tune-up of the Cummins engine.

II -- FRONT END SUSPENSION AND AXLE

This part of the unit will be a very brief discussion on different types of front end suspension and front axle arrangements found on vehicles today. In later units there will be a much more detailed coverage of these items.

SECTION A -- HISTORY OF FRONT AXLES

Up to about 1930, all four-wheel vehicles had front axles, but since the advent of front independent suspension such axles are no longer being used for passenger cars. However, practically all commercial vehicles and four-wheel tractors have front axles. The conventional front axle is of the divided type consisting of an axle center and two steering knuckles, pivotally connected to the center. In most of the early vehicles, the front axles were straight, the center portion being in line with the spindles of the steering knuckles. Later, when the engine was located in the front, either it or a drop-type cross member of the frame came directly over the axle, and this necessitated "dropping" the axle at the center to prevent interference. Still later, when the center of gravity of road vehicles had to be lowered for the sake of stability, the entire center portion of the axle center, including the spring pads, was dropped. These three stages in front axle development are shown in Figure 5. The lower one in the figure is typical of axles used in off-highway equipment.

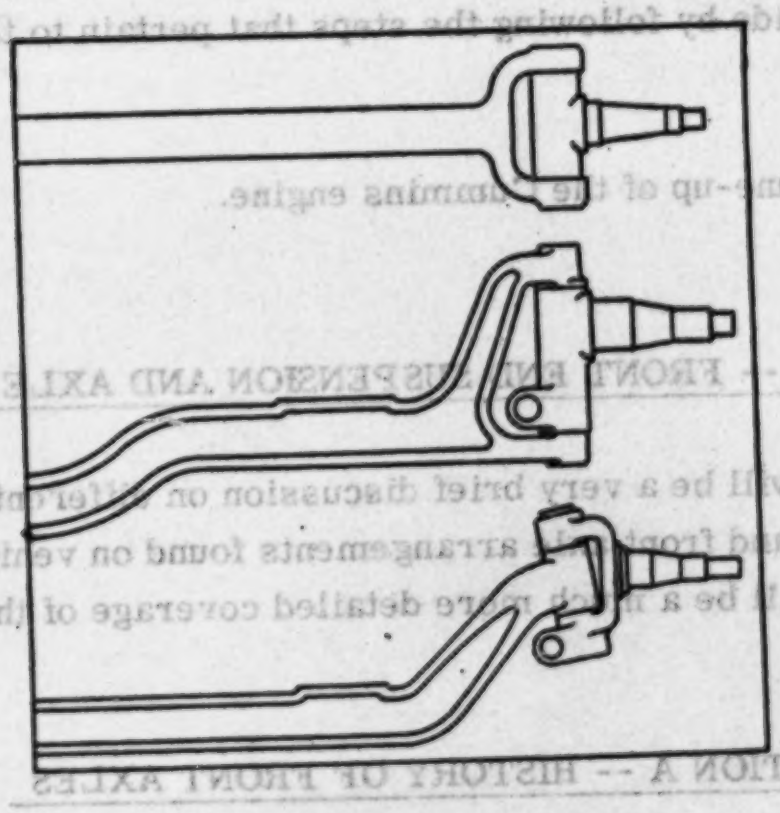

Fig. 5 Three front-axle types.

SECTION B -- AXLE LOADS

TWO LOADS -- Front axles are subjected to two basic loads or stress -- that due to the load supported, and that due to the braking movement or torque. With the vehicle at rest, the axle acts as a beam supported near its ends, directly over the center points of tire contact on the ground, and loaded at some distance from the supports -- at the centers of the spring pads. The load subjects the axle to a vertical bending action which, starting at zero at each point of support, increases uniformly to the center of the spring pad, and remains constant between the spring pads, if the load due to the axle itself is neglected.

MOTION LOADS -- When the vehicle is in motion, road shocks increase the vertical bending action. There is also horizontal bending action

because of the resistance of the front wheels when the vehicle is in motion. Under ordinary conditions, the latter stress is only about 15 lb. per 1000, this horizontal bending is only between 1 or 2 percent of the vertical bending action and is therefore negligible. It may be of considerable importance, however, when the front wheels drop into a hole, or rub a curb.

This has been a brief discussion of front axles and suspension, more will follow.

DIDACTOR PLATES FOR AM 1-19D

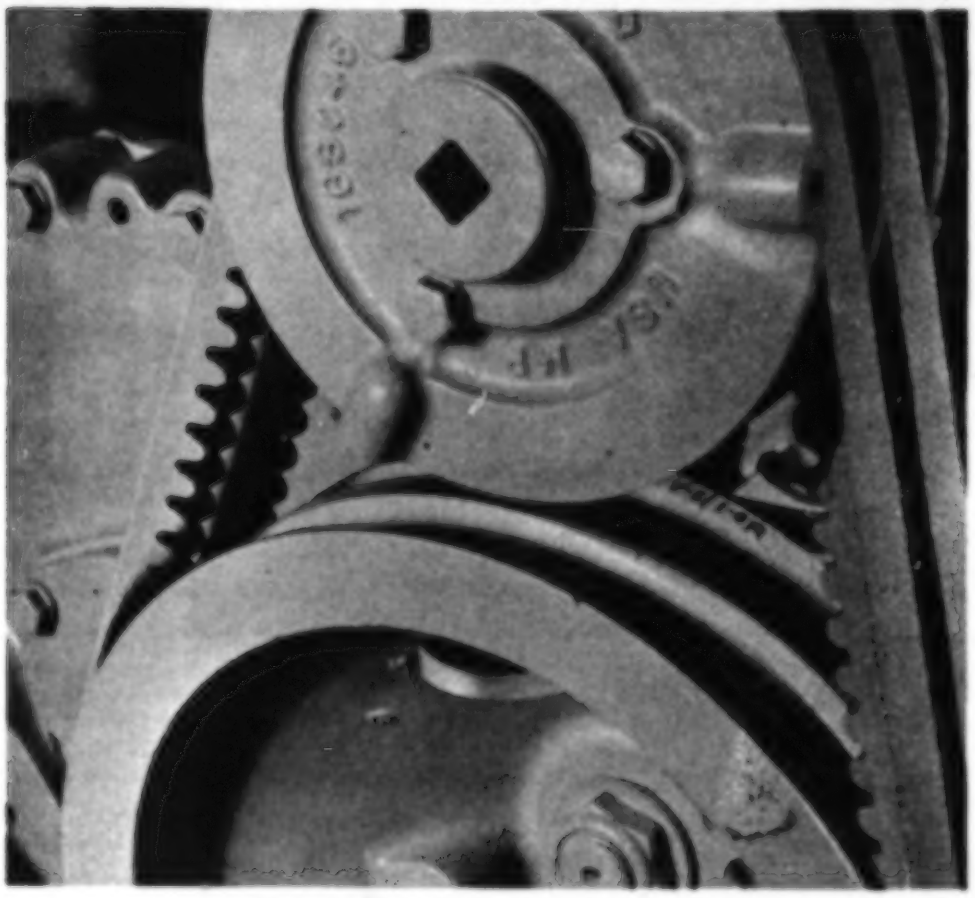

Plate I Valve set timing marks, water pump drive pulley.

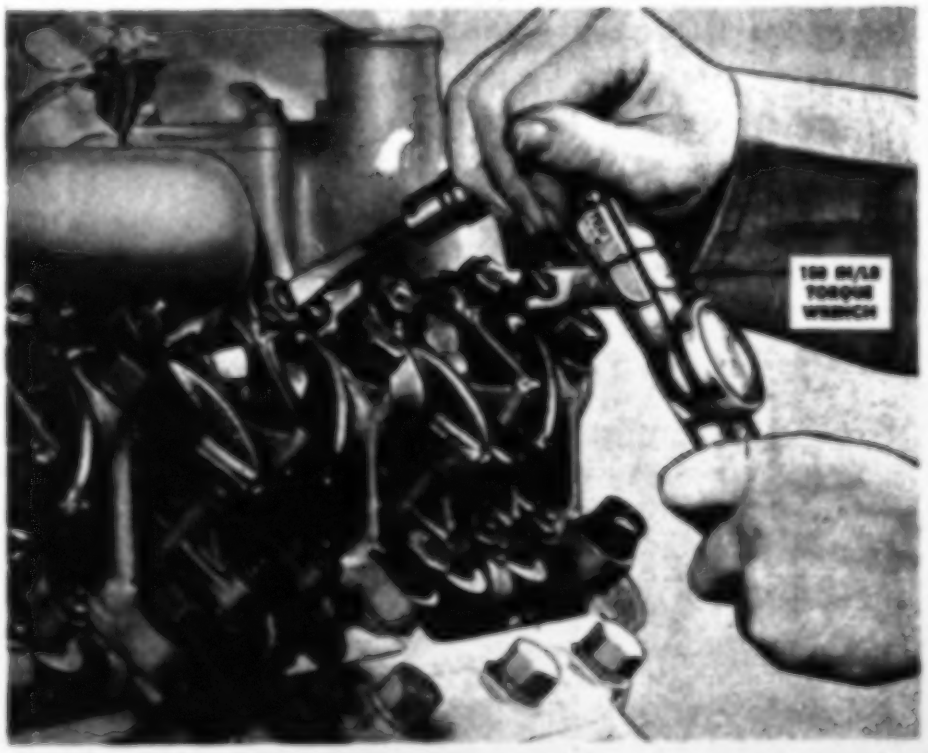

Plate II Adjusting injector.

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AM 1-19D
7-22-66

PRINCIPLES OF TUNE-UP --
CUMMINS DIESEL ENGINE

Human Engineering Institute - Minn. State Dept. of Ed. Vocational Education

Press A 1 Check to see that timer is OFF

1

1

This film lesson is designed to supplement the class text, AM 1-19, Engine Tune-Up -- Cummins Diesel Engine, by explaining the "whys" behind engine tune-up. In the Unit, we discussed the procedure required to tune the Cummins engine.

In this film, we will see what can happen if the procedure is not followed, and why problems occur if a tune-up is not accurately performed.

Press B 2

1

2

Injection timing -- or the mechanism that forces the injector open, allowing fuel to enter the cylinder in the Cummins engine -- is controlled by the movement of the injector push rod.

In the Cummins engine there are ___(1)___ push rods per cylinder. Of these the ___(2)___ one is the injector push rod. (Choose the two words that best fit the two blanks).

3 A. (1) two (2) smallest
4 B. (1) three (2) largest
3 C. (1) three (2) smallest

1

3

No. Your answer is incorrect. We said there were three push rods, that the middle one controls the movement of the injector and that it was the largest tube of the taree.

Press C 4

1

4

OK. The largest of the three push rods operates the injector. We also learned that the movement of the push rod is caused by the lobes on the camshaft.

If the camshaft lobe starts to lift the push rod before it should, the timing is said to be ___(1)___. If the push rod is lifted after it should, the timing is said to be ___(2)___.

5 A. (1) retarded (2) advanced
6 B. (1) advanced (2) retarded
5 C. (1) late (2) early

1

5

No. (Retarded/late), and (advanced/early) are both wrong answers.

If the push rod is lifted too early, the timing is advanced.

If it is lifted too late, the timing is retarded.

Press A 6

1

6

Correct. Usually when the timing is advanced, or early, the fuel is injected into the cylinder too soon, causing pre-ignition; this causes "fuel knock".

When the fuel is injected late and the piston is past top dead center (TDC), there will be a considerable loss in power, resulting in black smoke escaping from the exhaust.

Black smoke, as we learned before, is caused by _____.

7 A. diluted lubricating oil
9 B. incomplete combustion
8 C. oil in the cylinder

1

7

You said black smoke is caused by diluted lubricating oil. This is incorrect.

Diluted lubricating oil results in poor lubrication, and if allowed to continue will damage the engine severely. Try this question again.

Press B 6

1

8

You said black smoke would be caused by oil getting into the cylinder. This is incorrect.

Oil burning in the cylinders escapes as blue smoke from the exhaust. Try this question again.

Press A 6

1

9

Correct, black smoke indicates that raw fuel has entered the cylinder after it should, causing incomplete combustion and resulting in burning fuel escaping through the exhaust valves.

Early injection, we said, causes fuel knock. This condition (fuel knock) can be caused either by the timing being out of adjustment, or by the engine being overloaded (lugging) or both. When the timing is off, fuel enters early and combustion occurs, retarding the piston from reaching TDC and resulting in knocking.

Press A 10

1

10

When the engine is overloaded (lugging), the rpm is usually low, and the accelerator is fully depressed, allowing the full charge of fuel to enter the cylinder. This situation (low rpm) does not allow a sufficient volume of air to enter the cylinder for combustion; hence there are fuel knocks resulting from early combustion.

Press A 11

1

11

In both instances, early injection, and lugging, there is the problem of _____.

12 A. too much fuel

13 B. not enough air

14 C. early combustion

1

12

You said too much fuel in both cases; this is not correct.

In lugging, the engine has too much fuel injected for the amount of air that is present. Think, and try this question again.

Press A 11

1

13

You said there was not enough air in both conditions, lugging and early injection. This is not true.

The lack of enough air occurs only during the lugging situation. Lugging, remember, means heavy load, low rpm and lots of fuel; hence we get early combustion.

Press A 14

1

14

OK. Early combustion is common to both situations causing engine knock.

INJECTION TIMING -- As we learned in the text, there are three methods of changing injection timing on Cummins engines, depending on the type of engine.

On 4 and 6 cylinder inline engines, retarded timing can be corrected by adding gaskets between the cam follower housing and cylinder block. This does not change the length of the rods; it only changes the time when the lobes on the camshaft hit the cam followers. The addition of one gasket, advances the timing approximately one degree.

To decrease the timing, gaskets are removed.

Press A 16

2

XC-15

15

You have answered one or more of the questions in this group incorrectly. Before moving on to new material, let's review this section. Read carefully, and think before answering the questions.

Press A 2

2

16

On Cummins V-6 and V-8 engines, where timing is slow or fast, the timing is adjusted differently. Instead of moving the push rod cam follower in or out, the camshaft gear is placed in a different position on the shaft by the insertion of different sized keys into the lock mechanism. Check the maintenance manual for these key specifications.

On the Cummins V-12 engine the timing is adjusted by the positioning of two dowel pins through the camshaft gear. On new parts (camshaft/gear) the timing is set; then holes for the dowel pins are drilled in place. Further adjustment can be made by using oversized dowel pins if required.

Press A 17

2

17

Let's review. On Cummins 4 and 6 cylinder inline engines, the injector and valve timing is changed by _____.

18 A. shortening or lengthening the push rods
20 B. changing the position of the cam followers
19 C. changing the position of the camshaft

2

18

You said on Cummins inline engines the push rods are changed in length. This is partially true, but they are not changed physically. They are moved only by adding gaskets. Remember, this allows the lobes on the camshaft to strike the cam follower rollers later or earlier, depending on whether the gaskets are added or subtracted.

Press B 20

2

19

You said the position of the camshaft is changed. This is incorrect for inline engines. Try this question again.

Press A 17

2

20

Correct. Only the positioning of the cam follower rollers is changed so the lobes on the camshaft strike the rollers earlier or later as the camshaft turns, depending on which adjustment is required.

On Cummins V-6 and V-8 engines, the injector and valve timing is adjusted by _____.

21 A. turning the camshaft at a different speed
33 B. camshaft drive gear keyed in a different position
22 C. reversing the present camshaft

2

21

You said "by turning the camshaft at a different speed"; this is incorrect. There is no adjustment for the speed of the camshaft. Read this question over and try again.

Press A 20

2

22

You said "by reversing the present camshaft" the injector and valve timing could be changed. This is incorrect. On some GM engines this can be done, but not on Cummins. Try this question again.

Press B 20

2

23

Correct. On V-6 and V-8 Cummins engines, the camshaft gear is keyed to a different position on the shaft to change the timing.

On Cummins V-12 series engines, if the injector and valve timing were set incorrectly, and the dowel holes on the camshaft gear were drilled accordingly, the most feasible way to remedy this is to _____.

24 A. obtain a new shaft and drill new holes
25 B. shim the gear up with washers
26 C. drill bigger holes and use oversized dowel pins

2

24

You said "obtain a new shaft and drill new holes". This is very expensive and is not necessary to correct this situation. Read this question over again and try another.

Press A 23

2

25

You said "shim up the gear with washers". This would only destroy the gear lash contact with the idler gear. This answer is incorrect.

The answer we want here is to drill bigger dowel holes and insert oversized dowel pins to correct for the adjustment.

Press A 26

2

26

Correct. Oversized dowel pins and larger holes is the correct method.

INJECTOR PLUNGER AND VALVE ADJUSTMENT -- When positioning the engine for injector and valve adjustment, it is necessary that No. 1 piston is TDC (on V's this would be No. 1 on the left bank) and that both the intake and exhaust valves are closed for this cylinder. This step is to be sure that _____.

27 A. the timing marks are aligned correctly
29 B. this piston is on the compression stroke
28 C. the compression release mechanism is working

2

27

You said "so that the timing marks could be aligned correctly". This is incorrect.

The compression stroke is needed here because -- if the injector plunger and valves were adjusted on the exhaust stroke -- the action of the plunger would break off the injector tip or bend the push rod when the high side of the cam came around.

Press A 29

2

28

You said "to be sure the compression release is working". This is incorrect.

The compression release only allows the engine to be barred over more easily. You recall in AM 1-19 text, we mentioned that the release lever must be unblocked before adjusting the injector plunger and valves. Try this question again.

Press A 26

2

29

Correct. The compression stroke is required because -- if the injector plunger and valves were adjusted on the exhaust stroke -- the action of the injector plunger would probably knock the injector tip off, or the push rod could be bent when the high side of the cam came around.

Remember -- two complete revolutions of the crankshaft are needed to set all injector plungers and valves. Injector and valves can be adjusted for only one cylinder at any one setting ("VS" mark); and that is the cylinder on the power stroke.

Press A 30

2

30

ADJUSTING INJECTOR PLUNGERS -- It is well to note again that the injector plungers must be set before the valves, because the upward flex of the rocker shaft when the injector is torqued would change the valve setting.

Before adjusting any of the injectors, the engine must be in the valve set position. This position is the _____.

32 A. compression stroke position
33 B. index marked position

X (C) 31

3

31

You have answered one or more of the questions in this sequence of material incorrectly. Before moving on, let's review this sequence again. Read carefully and take your time in answering.

Press A 14

3

32

You said "the compression stroke position". This is incorrect.

The engine must be set at the indexed marked position for the particular injector and valves to be adjusted. These marks are located on the pulley of the fuel pump accessory drive gear. See Plate I.

Press A 33

3

3

OK. The engine must be at the valve set (VS) position before the particular injector to be adjusted can be adjusted. These marks are located on the pulley of the fuel pump accessory drive gear on most Cummins engines; see Plate I.

Before loosening the screw to adjust the injector plunger, there is a very important step to perform. This is to be sure all the oil (fuel) has been removed from the injector cup. This is to prevent getting a false setting from hydraulic build-up in the injector when the torque wrench is used.

Press A 34

3

34

When tightening the adjusting screw (see Plate II) the torque wrench should have a screw driver attachment and should read in one foot-pound or inch-pound divisions. A foot-pound scale should have no more than a potential of 15 foot-pounds. This maximum torque is to prevent overtightening of the screw.

Should the injectors be set too tight, _____.

37 A. the fuel would be metered late and the injection of fuel would be early

35 B. the fuel would be metered for a longer period of time, and the exhaust would be black

36 C. the injection of fuel would be late and detonation of fuel would occur

3

35

You said "the fuel would be metered for a longer period of time and the smoke would be black". This is incorrect.

The metering period (time lapse) cannot be changed, but it can be early or late. In this case it would be late if the injectors are too tight.

As for the smoke being black, we said earlier that this is a fuel/air problem. Adjusting the plunger would have nothing to do with this.

Press A 37

3

36

You said the injection of fuel would be late. Actually, it would be the opposite. When the adjustment is too tight, it is the same as advancing the injection of fuel. Also, one of the reasons for detonation is early injection of fuel.

Press A 37

3

37

OK. If it is adjusted too tight, the push rod will be bent and the camshaft will rotate many degrees before the slack is taken up and the injector plunger starts to move. This causes a delay in metering. This also accounts for the fuel injection being early. The injector plunger is too long and will start down before it should.

Press A 38

3

38

When the injector plungers are set too loose _____.

39 A. the injector may work loose from the cylinder head and cause misfiring in the engine

41 B. there will be prolonged metering and injection timing will be late, causing black smoke and poor economy in operation of the engine

40 C. there is a possibility of knocking the injector tip off

3

39

You said "the injector may work loose from the cylinder block". This answer is incorrect.

The injectors are held in place by studs and nuts. Whether the plunger adjustment is tight or loose would not affect movement of the injector housing. Try this question again.

Press A 38

3

40

You said "the injector tip may be knocked off". This answer is incorrect.

Actually, the plunger would never reach the bottom of the cup if the adjustment were too loose. Try this question again.

Press A 38

3

4

OK. If the injector plunger is adjusted loose, the plunger will move up earlier than it should and the metering hole (within the injector) will be uncovered sooner. Also, the push rod is shorter and the injector plunger will not move down when the camshaft rotates. This condition causes metering to last longer because the hole is open longer. Also, injection is late.

Press A 41-1

3

41-1

VALVE CROSSHEAD ADJUSTMENT -- Probably the most important consideration to remember when adjusting the valve crosshead is to be sure there is a minimum of .025" clearance between the valve spring retainer and the crosshead. Should this clearance be adjusted wrong, the _____.

44 A. rocker arm may bend the bridge guide
42 B. valves would open farther than they should
43 C. engine would be noisy from slapping action

3

42

You said "the valves would open farther than they should". This is incorrect.

If the clearance is less than it should be or greater, there is a good chance of bending the bridge guide. This condition would cause one valve to open more than the other.

Press A 44

3

43

You said "the engine would be noisy from slapping action". This is possible, but more than likely the bridge guide would become bent due to the rocker arm striking it at an angle. Also, one valve may open farther than the other if the bridge is cocked on the guide.

Press A and try this question again. 41-1

3

Correct. This clearance is critical; any misadjustment here could bend the bridge guide when the rocker arm hits it at an angle which is typical of the Cummins engine.

VALVE ADJUSTMENT -- Here as in the valve crosshead adjustment, the clearance between the crosshead and rocker arm is very critical. If this adjustment is greater than is specified the _____.

47 A. valves will not open far enough and may burn
45 B. push rods travel less distance to open the valves
46 C. valves are open all the time after expansion

3

45

You said "the push rods travel less distance". This would mean little or no slack. This is incorrect.

If the clearance was in excess of .025", there would be more slack to take up before the valve opened. This would cause insufficient valve clearance between the head and seat and would cause the hot exhaust gases to act as a torch; hence: valve burning.

Press A 47

3

4

You said "the valves would be open all the time after they heat up". This is incorrect.

With excessive clearance, even the expansion from heat would not take up the slack between the rocker arm and the crosshead. Try this question again.

Press A 44

3

47

Correct. Too much clearance will cause the valves to open only part way, because of the excess slack involved in the mechanism. This condition hinders the escaping exhaust gases, and the hot gases act as a torch, passing through the small opening and burning the valves.

Press A 48

3

48

FUEL PUMP ADJUSTMENTS -- There are FOUR important things to remember when adjusting Cummins fuel pumps on the engine:

1. Accuracy of adjustments is dependent on engine condition and the accuracy of the instruments used.
2. Adjustments should be made when engine is at operating temperature (140° to 160°).
3. The valves and injectors must be set before attempting adjustments on the pump.
4. The fuel system must be purged of air.

Press A 50

X (C) 49

4

49

You have missed one or more of the questions in this section. Before going on, let's review this data again. Read carefully, and take your time in answering.

Press A 30

4

50

The way to tell if air is purged from the fuel system is _____.

52 A. to release throttle; if engine stops, there is air in the system, or leaks in the suction lines

51 B. that throttle has no effect on rpm

51 C. that the engine will not shut off

4

51

You said either "when the throttle has no effect on rpm" or "the engine would not shut down". These are incorrect.

If there is still air in the system (usually caused by leaks in the suction lines) the engine will stop when the throttle is released.

If the engine has been running for three minutes at 600 to 800 rpm (mentioned in AM 1-19) it will purge itself, unless there are leaks in the suction line.

Press A 52

4

52

Correct.

In adjusting the Cummins fuel pump, the "snap reading" refers to measuring _____.

53 A. vacuum reading

54 B. fuel pump psi

55 C. manifold pressure

4

53

You said the "snap reading" refers to the vacuum reading. This is incorrect.

The vacuum gauge is placed between the fuel filter and the pump, to measure restriction of flow of fuel from the fuel tank. Try this question again.

Press A 52

4

54

You said "snap reading" refers to fuel pump psi. This is incorrect.

What we are after here is not fuel pump pressure but manifold pressure, which is the fuel pressure that is controlled by the throttle passage.

Press A 55

4

55

Correct. A word of caution should be mentioned at this point. The Cummins shop manual warns that the ANEROID (discussed in AM 1-13D), must be disconnected to reach maximum manifold pressure during the short acceleration period, (sometimes referred to as " snap reading") on TURBOCHARGED engines only.

Press A 56

4

56

Fuel filter restriction has been mentioned and should be covered in more detail at this point. The most accurate method of determining fuel restriction is with a vacuum gauge (tool # ST-434). If restriction reads 8 to 8.5 inches vacuum while the engine is running at full speed and load, change the element or remove other sources of restriction.

When the restriction becomes as great as 10 or 11 inches vacuum, one of the following will happen

57 A. the engine will not reach rated rpm
58 B. the engine will lose power
57 C. the engine will not run

4

57

No. You said "the engine will not reach rated rpm". It will reach rated rpm, but will not carry rated load, because of the lack of fuel.

Press A 58

4

58

Correct. The engine will lose power due to the lack of fuel being delivered from the pump to the manifold through the throttle shaft fuel passage. The restriction reduces the volume of fuel and can be corrected by replacing the filter element, as outlined in the shop manual.

Press A 59

4

59

It is not important to remove and clean the PT fuel pump filter screen as the residue and foreign particles are trapped in the fuel filter ahead of the screen. This statement is:_____.

60 A. True
61 B. False

4

62

Wrong. An explanation is on the next frame.

Press A 61

4

61

Correct. The filter screen contains a small magnet and the magnetic action will trap any ferrous metal particles that may enter the fuel system. Over a period of time, the gear pump teeth have minute particles that break away and flow along the fuel. If they were not trapped by the filter screen and the magnet, the particles would end up in the injectors and cause severe scoring of the plunger and barrel.

Press A 62

4

62

If the fuel pump has been removed from the engine for rebuild or repairs, proper hook-up is necessary, as outlined in the shop manual. How can the two pumps (PTR and PTG) be identified? They are not connected alike.

63 A. The above statement is false; both pumps are connected alike.
64 B. The information plate is marked "PR" for the PTR pump and the PTG pump is marked with "GR".
63 C. The pressure regulator on the PTG is on the top of the pump instead of the side.

4

63

Wrong. The name plate (information plate) on the pump identifies the type of pump you are about to install. The PTR pump is identified by the letters "PR" and the PTG pump is marked with the letters "GR". The PTR pump pressure regulator cap which is located on the back of the pump is a 15/16" hex head type, whereas the PTG cap in the same location has an allen or plug socket for tightening.

Press A 64

64

OK. Another way of distinguishing the PTG pump from the PTR is: the PTG pump usually has a hex head plug in the pump fuel return line on top of the pump, that isn't normally used. PTG fuel is recirculated in the pump case rather than returned to the supply tank. The only return line on the PTG pump is from the injector fuel manifold.

Press A 65

65

Why is it necessary to know if you are about to install a "PTG" or a "PTR" pump, since they appear to be very much alike?

64 A. It makes little or no difference.
66 B. The engine would not run if the wrong pump was installed.
67 C. The "PTR" pump has a separate fuel return line to the supply tank that may not be provided if a "PTR" pump is installed in place of a "PTG" pump.

66

No. It does make a difference; they are not intended to be interchangeable without some modification. If a "PTR" were installed instead of a "PTG" and the return line fitting plugged, as it appears to be in the "PTG", the engine would (in all probability) start up as usual and then overspeed and run out of control.

Press A 67

67

OK. We agree that the pumps are not intended to be interchangeable without some modification. When the correct pump has been installed and the engine run long enough to purge the air from the fuel system, we find the manifold pressure too high (pressure taken by the snap method), what could be the end result of the excessive fuel pressure?

68 A. Fuel manifold may rupture.
68 B. Engine may run away.
69 C. Engine may be damaged due to excessive amount of fuel being injected.

68

No. It is not likely that the fuel manifold would rupture, and it is unlikely that the engine would run away; but the engine could be damaged by excessive amounts of fuel. The metering of fuel depends upon time and pressure. If the pressure is too high, too much fuel will be injected into the cylinder, resulting in overfueling and possible damage to the engine.

Press A 69

69

OK. How would an engine act if the rear throttle stop screw is set incorrectly, or works loose due to vibration?

71 A. Under heavy load the engine will not develop rated power and torque.
70 B. Fuel manifold pressure may be too high and engine will overspeed.
70 C. There will be an incorrect amount of throttle leakage.

70

No. The fuel manifold pressure is adjusted by adding or removing shims, (MP shims) on the fuel adjusting plunger, and the throttle leakage is adjusted by the forward throttle stop screw. The rear throttle stop screw controls throttle over-travel, and insures that the main fuel passages are indexed, (properly aligned). If the fuel passages are not aligned properly, there will be a restriction in the fuel flow, and a loss of power and torque.

Press A 71

71

OK. How would an engine act if the forward throttle stop screw was set to allow too much throttle leakage?

73 A. The engine will decelerate too slowly.
72 B. Engine will surge at governed rpm.
72 C. Engine will die or stall.

No. The answer we want here is that the engine will decelerate too slowly because of the manifold pressure remaining high longer. The recommended deceleration period is 6 seconds.

Press A 73

73

OK. You are correct. If the forward throttle stop screw is adjusted to allow too much throttle leakage, the manifold pressure will remain high longer and the engine will not decelerate within the 6 seconds recommended. Under this condition, the possibility of damaging the transmission increases.

Press A 74

74

How is manifold fuel pressure adjusted on PT pumps?

75 A. With rear throttle stop screw.
75 B. By adding or removing shims from the governor spring pack.
76 C. By adding or removing shims from the fuel adjusting plunger.

75

No. The rear throttle stop screw is used to index the main fuel passages, and the spring pack is provided to change the high idle, no load speed.

Press A 76

76

Yes. Removing shims from the PTR pump will reduce pressure, and removing shims from the PTG pump will increase pressure.

In most cases, fuel pump adjustments are made on a test stand, and care must be taken to prevent dirt and foreign matter from entering the system. Past experience has proven the necessity of having specially trained personnel for the pump and injector repairs and adjustments.

Press A 78
X(C) 77

77

You have missed one or more of the questions in this section on fuel pumps and fuel pump adjustments. Before going on to the final review of this film, go over this section again. Read carefully, and take your time on answering.

Press A 48

78

For review, let's recall some of the important points of this lesson that should be kept in mind after you have completed the lesson.

If the camshaft lobe starts to lift the push rod before it should, the timing is said to be ____(1)____.
If the push rod is lifted after it should, the timing is said to be ____(2)____.

79 A. (1) retarded (2) advanced
80 B. (1) advanced (2) retarded
79 C. (1) late (2) early

79

No. (Retarded/late) and (advanced/early) are both wrong answers.

If the injector push rod is lifted before it should, the timing is said to be advanced.

By the same token, if the push rod is lifted after it should, the timing is said to be retarded.

Press A 80

5

80

OK. Let's try another.

Usually, early injection will cause _____.

82 A. fuel knock
81 B. blue smoke
81 C. oil smoke

5

81

You said early injection causes "blue smoke" or "oil smoke"; both of these answers are incorrect.

Early injection refers to fuel being injected early, which causes fuel knock. Blue smoke is a result of oil burning in the cylinders.

Press A 82

5

82

OK. Fuel knock caused by pre-ignition is a result of early fuel injection.

Late or retarded injection of the fuel in an engine refers to fuel entering _____ _____.

84 A. after the piston has passed TDC
83 B. before the piston has reached TDC
83 C. after the piston has passed BDC

5

83

No. Fuel injected before TDC and after BDC would be advanced timing, or fuel injected before it should be in relation to the piston on the up-stroke.

The correct answer is: fuel entering the cylinder after the piston has reached TDC.

Press A 84

5

84

OK.

Excess fuel burning in the cylinder always escapes from the exhaust as _____ smoke.

85 A. blue
87 B. black
86 C. white

5

85

No. Blue smoke escaping from the exhaust indicates oil burning in the cylinder(s), not fuel. The correct answer is "black smoke".

Press A 87

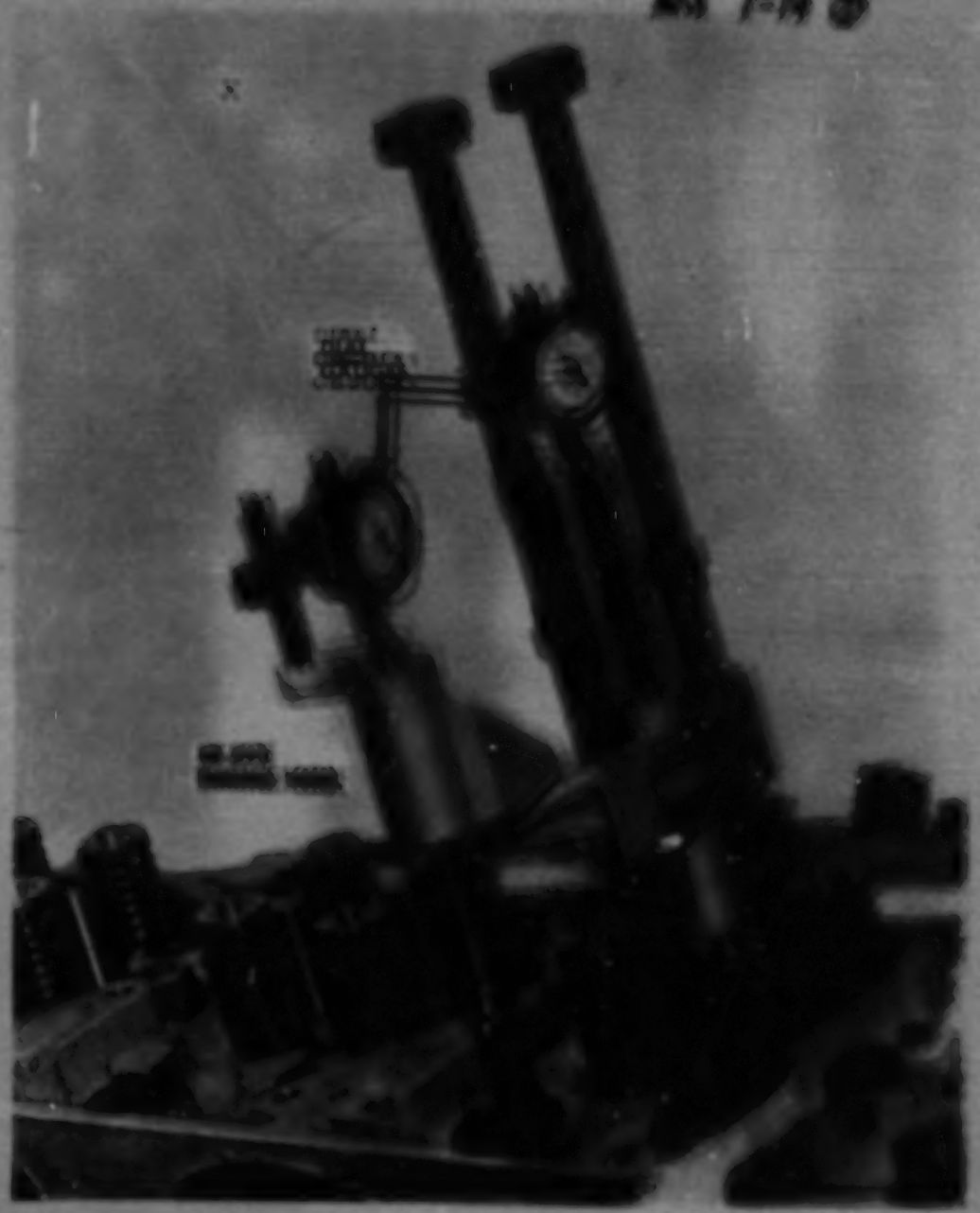
5

86

No. White smoke is expelled from the exhaust usually when a diesel is first started and the zone surrounding the combustion area is cold. The correct answer here is "black smoke", indicating fuel burning.

Press A 87→REWIND

5



ST-593 Injector Timing Fixture

HUMAN
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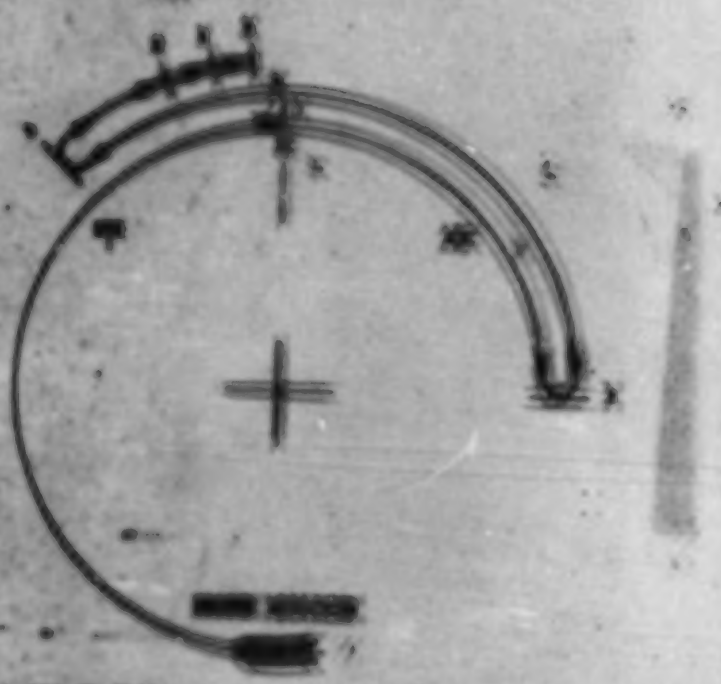
Cleveland, Ohio 44115



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INSTRUCTOR'S GUIDE

Title of Unit: I -- Engine Tune-Up -- Cummins Diesel Engine
II -- Front End Suspension And Axles

AM 1-19
7-19-66

FIRST: Be sure all questions have been answered that students might have on home study units.

OBJECTIVES:

1. To familiarize the student with tune-up of the Cummins engine without removing components from the engine or using test stand equipment.
2. To give the student some theory behind tune-up, not just present him with procedures; although some procedures are included.
3. To once again show the difference between the PTR and PTG Cummins fuel pump and how to adjust them.
4. To briefly cover the history of front end suspension and axle designs.

LEARNING AIDS suggested:

Vu-Graph Cells:
AM 1-19 (1) ST-593 Injector Timing Fixture
AM 1-19 (2) Engine Timing Procedure

Models: Components such as injectors or a fuel pump would be beneficial to bring to class.

QUESTIONS FOR DISCUSSION AND GROUP PARTICIPATION:

1. Although vehicle performance records are maintained, what is still necessary for the diesel mechanic to know?
2. How many hours should a new engine run before a tune-up is necessary?
3. On the Cummins engine, how is injector timing controlled?
4. How is injector timing checked?
5. What is meant by compression release?
6. Where are the timing marks located on the Cummins engine?
7. Why bring the engine up to operating temperature before tune-up?
8. Why is it necessary to set the injector plungers before the valve?
9. How many push rods per cylinder are there? Why are they hollow?
10. Is the same engine position used when adjusting the intake and exhaust valves as is when setting the injector?

11. How can a PTR fuel pump be distinguished between a PTG type?
12. Does the PTG type pump ever require priming?
13. What is meant by the designation "mp"?
14. How is "mp" raised or lowered?
15. What are the two types of load placed on a front axle?